RECLAMATION

Managing Water in the West

Discharge to Habitat Relationships for Anadromous Salmonid Juveniles in the Stanislaus River

DRAFT STUDY PLAN 2007

Central Valley Project
Mid-Pacific Region

U.S. Department of the Interior
Bureau of Reclamation

April 11, 2007

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Contents

Figures and Tables

Figures

Tables

Discharge to Habitat Relationships for Anadromous Salmonid Juveniles in the Stanislaus River
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1 Summary

The Central California Area Office, in cooperation with the Denver Technical Service Center and the Mid Pacific Regional Office, is planning field surveys in 2007 in an effort to describe the discharge to habitat relationship for fall run Chinook salmon *(O. tshawytscha)* and steelhead (*O.mykiss*) juveniles in the Stanislaus River. This is the first year of a 4-year study to volumetrically map mesohabitats in the lower Stanislaus River at 5 different discharges. We propose to accomplish this by 1) describing microhabitat use and selectivity by anadromous salmonids, 2) estimating the availability of preferred microhabitat positions within different mesohabitat types, and 3) estimating the total useable habitat at five discharges using a combination of hydraulic modeling, LiDAR, geographic information system (GIS) analysis, and field mapping of mesohabitats in the LSR. The goal of this study is to provide managers, stakeholders, regulatory agencies, and the public with a tool to evaluate discharge requirements for juvenile salmonids and aid in the development of a flow prescription for the Stanislaus River. The objective of this study is to develop a GIS tool to allow: 1) visualization and comparison of juvenile salmonid habitat at five discharges, 2) investigation of habitat and fish density, 3) description of microhabitat availability within mesohabitat types, and 4) mapping of mesohabitats along the lower Stanislaus River.

2 Introduction

2.1 Purpose

The purpose of this study plan is to describe the overall study design, field survey methods, and analytical approach for mapping juvenile salmonid habitat on the Stanislaus River.

2.2 Background

This study plan originated from a proposal to the Reclamation Science and Technology Program (S&T) titled *Saving Water and Insuring Delivery – Flow Prescription and the Discharge to Habitat Relationship for a Listed Anadromous*

Salmonid (Appendix A). The goal of this proposal (Scale-up Study) is to develop a tool to help managers and stakeholders evaluate discharge requirements for juvenile salmonids in the Stanislaus River. This effort is intended to build on the efforts of the Fisheries Foundation of California (FFC) Stanislaus Habitat Use Pilot Investigation (SHUPI) and "scale up" to describe the discharge to habitat relationship for juvenile salmonids within the entire 58.4 miles of the lower Stanislaus River (LSR).

The SHUPI will provide habitat and fish survey data in five ½ mile reaches at two discharges (300 and 1500 cfs). The SHUPI will provide a statistical comparison of mesohabitat and fish distribution between two discharges using empirical field data and 2-D hydraulic modeling. The Scale-Up Study will utilize the habitat and fish survey data provided by the SHUPI to describe fish densities in mapped mesohabitat polygons in each of the river segments. The final study design for the SHUPI is being developed in coordination with the Scale-up Study to ensure consistent methodologies in mesohabitat classification and mapping procedures See Section 3.2 Coordination with SHUPI for additional discussion on how these two studies fit together.

The Scale-up Study was awarded $40K by the S&T Program in FY07 with additional $120K of funding provided by the Central California Area Office. This is the first year of a 4-year study to describe the discharge to habitat relationship for juvenile Chinook salmon and *O.mykiss* at 5 different discharges (200, 300, 700, 1200, and 1500 cfs).[1]

2.3 Context

2.3.1 New Melones Revised Plan of Operations

Public Law 108-361 directs the Secretary of the Interior to update the New Melones operating plan to "reduce the reliance on New Melones Reservoir for meeting water quality and fishery flow objectives, and to ensure that actions to enhance fisheries in the Stanislaus River are based on the best available science." In order to update the existing operating plan, Reclamation proposes to develop a revised plan of operation (RPO) for New Melones Reservoir. As part of this effort, Reclamation is conducting the biological studies needed for managers and stakeholders to evaluate instream flow requirements for juvenile salmonids and ultimately develop a flow prescription (i.e. flow schedule).

2.3.2 1987 Agreement

Reclamation and the California Department of Fish and Game (DFG) entered into an agreement in 1987 (1987 Agreement) which allowed for the withdrawal of the

[1] We recognize that we may not be able to work at these exact discharges. The exact discharges will be dictated by Central Valley Project operations and will be dependent on water year type.

protest by DFG against Reclamation's application for permits to divert water for beneficial uses at New Melones Reservoir. The combined purposes of the1987 agreement include: 1) providing appropriate Stanislaus River instream flows as needed to maintain or enhance the fishery resources during an interim period in which habitat requirements are better defined, and 2) completing studies of Chinook salmon fisheries of the Stanislaus River. A seven–year study program was developed jointly by Reclamation, DFG, and the US Fish and Wildlife Service (FWS) which included seven study elements, a schedule, estimated budget, along with the recognition that completion of the studies was contingent upon approval of the participating agencies respective budgets. The seven study elements described in the 1987 Agreement are:

1) Evaluate instream flow requirements
2) Evaluate distribution and growth of juvenile salmon
3) Define timing and magnitude of downstream migration
4) Determine annual spawning escapements
5) Evaluate spawning habitat suitability and improvement needs
6) Temperature stations and modeling
7) Coordinate and integrate studies

Under the 1987 Agreement, the FWS conducted studies to evaluate instream flow requirements for salmonids. Aceituno (1990) evaluated microhabitat use and availability for Chinook salmon. Then, the Instream Flow Incremental Methodology (IFIM) was applied to describe the relationship between instream flow and habitat availability for Chinook salmon in the Stanislaus River between Goodwin Dam and Riverbank (Aceituno 1993).

The Scale-up Study is intended to provide Reclamation and stakeholders with additional biological data to address the study elements identified in the 1987 Agreement and help form the scientific basis for evaluating instream flow schedules for the New Melones RPO.

2.3.3 Stakeholder Coordination

The concept for this study is based on informal scoping of resource agencies, regulatory agencies, and stakeholders to identify the biological information needed to address the remaining elements of the 1987 Agreement and support the development of an instream flow schedule for the New Melones RPO process. One gap in the biological information that continued to arise during these informal discussions was the need to understand how juvenile salmonid habitat changes relative to changes in discharge because instream flow management relative to fish species in the Stanislaus River focuses on the needs of Chinook salmon and steelhead trout. The product of this study is intended to help fill this information gap by providing a GIS tool that Reclamation and interested stakeholders alike can use to evaluate the habitat-discharge relationships for juvenile salmonids in the LSR.

2.4 Developing a Flow Prescription

A flow prescription defines instream flow requirements throughout the year and can be based on balancing competing needs of a system including: water delivery to meet consumptive demands, biological requirements, water quality standards, and regulatory requirements of water rights, (NRC 2005). One example of what a generic flow prescription may look like is illustrated in Figure 1.

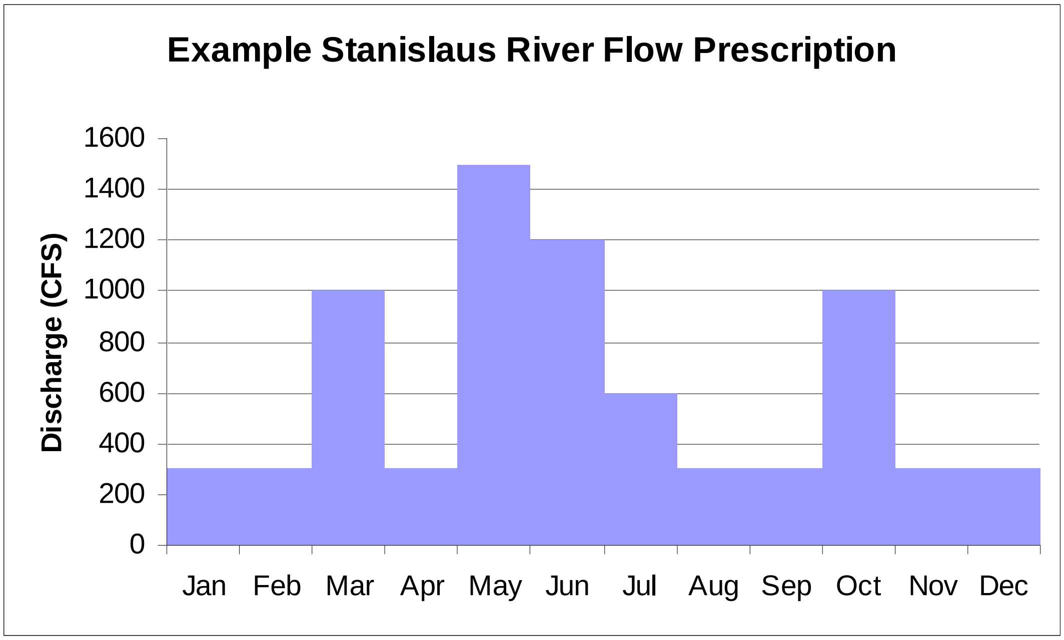


Figure 1: Example of a flow prescription that identifies instream flow levels on a monthly time-step.

There is currently insufficient biological information available to develop a precise flow prescription for the Stanislaus River. To develop a flow prescription requires a tool to compare and evaluate how the amount of suitable habitat for juvenile salmonids changes at different discharges. The product of this study is a comparative GIS tool that will aid managers and stakeholders in developing and evaluating proposed discharge requirements for juvenile salmonids.

3 Study Design

This section provides an overview of the study design, including specific details regarding microhabitat parameters, mesohabitat classification, and river segments. It also describes the hierarchical approach to scale-up the habitat to discharge relationship for the all 58.4 miles of the lower Stanislaus River (LSR).

3.1 Objective

The objective of this study is to provide managers, stakeholders, regulatory agencies, and the public with a GIS tool to evaluate discharge requirements for juvenile salmonids and aid in the development of a flow prescription for the LSR.

3.2 Coordination with SHUPI

The SHUPI will provide habitat and fish survey data in five ½ mile reaches at two discharges (300 and 1500 cfs). The habitat data will consist of mapped mesohabitat polygons in a GIS for each of the ½ mile reaches and 2-D hydraulic modeling in two subsample ¼ mile reaches. Fish survey data will include fish densities (obtained via snorkeling) in mapped mesohabitat polygons for each of the ½ mile reaches and field tests of alternative survey methods (e.g. electroshocking, seining) to provide fish density data in areas of the river with low visibility. The final study design for the SHUPI is being developed in coordination with the Scale-up Study to ensure consistent methodologies in mesohabitat classification and mapping.

The SHUPI will provide fish survey data at 300 and 1500 cfs. For the Scale-up Study, we are assuming that juvenile salmonid microhabitat use is the same at 300 and 1500 cfs as it is at 200, 700, and 1200 cfs.

3.3 Overview

The proposed study will:

1. Describe microhabitat use for juvenile Chinook salmon and steelhead using five parameters including: depth, velocity, shear, distance to cover from predation, and distance to bank (DEP, VEL, SHE, DCP, DTB).
2. Estimate availability of microhabitat parameters within six mesohabitat types. Mesohabitats will be based on three water velocity categories and two edge categories (Section 3.6 Mesohabitat Types).
3. From microhabitat use and availability, develop selectivity values for each of the five microhabitat parameters for each life stage of interest. Develop the selectivity values for each of three fish densities (see Sidebar 1 - Density Dependence).

Sidebar 1 - Density Dependence

We intend to analyze the GIS using microhabitat selectivity data for each of three life stages: 0+ O. mykiss, 1+ O. mykiss, and 0+ Chinook salmon. While collecting the microhabitat use data, we will also collect the density of fish in that same polygon where a particular fish was located. After all the data are collected, we will analyze the density data and select three categories of density: low, medium and high. Those definitions will be based on natural breaks in the distribution of fish density. Then we will calculate selectivity indices for all five microhabitat parameters for each life stage at each of the three densities. Then we will use the GIS to determine how much habitat is available for each life stage at low, medium, high density.

4. For each life stage, determine three multi-variate functions (Sidebar 2 – Multi-variate Function), one for each of three fish densities. The function will provide probability of use based on selectivity values of (DEP, VEL, SHE, DCP, DTB).
5. Determine mesohabitat availability in three river segments at five different discharges by remote sensing, hydraulic modeling, GIS analysis, and field surveys.
6. Develop a GIS tool that delineates mesohabitats including volume for the entire LSR.
7. Use a hierarchical approach to combine microhabitat selection, mesohabitat quantity, hydraulic modeling, and GIS analysis to estimate the volume of useable habitat available at each of five discharges (200, 300, 700, 1200, and 1500 cfs).
8. If a relationship exists between mesohabitat categories and fish density, use density data to estimate how many juvenile O.mykiss (0+, 1+) and Chinook salmon (0+) the river can support at each discharge. Develop estimates for each of the three fish densities to account for density dependence. Compare results to outmigration estimates from the rotary screw traps and snorkel counts.
9. Share the GIS with stakeholders etc. Anyone can then use the GIS to investigate habitat and discharge relationships for juvenile salmonids in the lower Stanislaus River.

Sidebar 2- Multi-variate Function

The principal research component of this study is to develop an acceptable method to estimate probability of use from the selectivity value of the five microhabitat parameters:

P (DEP, VEL, SHE, DCP, DTE) =
$A\ \alpha_{VEL}, B\ \alpha_{DEP}, C\ \alpha_{SHE}, D\ \alpha_{DCP}, E\ \alpha_{DTE}$

Where,
P = Probability of Use
DEP = Depth (m)
VEL = Focal velocity at the nose of the fish (cm/s)
SHE = Velocity shear (cm/s per cm)
DCP = Distance to cover from predation (m)
DTE = Distance to edge (m)
A, B, C, D, and E = Weights of each of the five microhabitat parameters.

The traditional PHABSIM approach loads depth, velocity, and substrate into the probability of use using a simple multiplicative function (Bovee and Cochnauer, 1977) and assuming all three variables are independent of one another. We are also aware of some other approaches that have been developed in recent years (e.g. logistic regression (Tiffan, 2002)).

We will evaluate known methods. If one is found suitable for this application we will employ it. If not, we will develop our own multi-variate function. This development will take place over the next 3 years. We will study possible approaches. Then we will propose an approach to the Stanislaus Fish Group to get their feedback. Next, we will develop the agreed upon multivariate function and evaluate it. Then, we will report back to the Stanislaus Fish Group on the formulation and performance of the function. We will iterate these steps until an acceptable multi-variate function is agreed upon.

3.3.1 Product

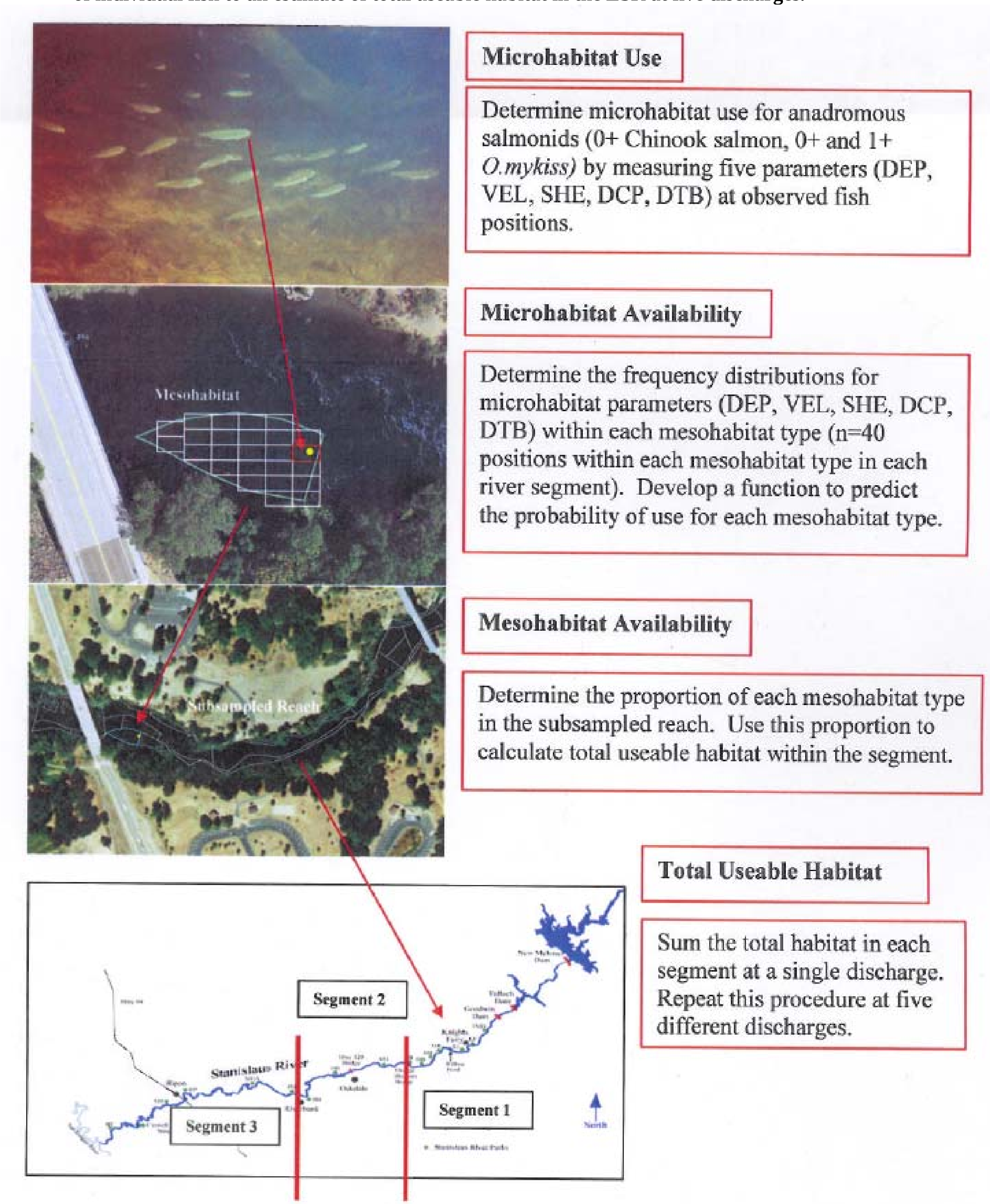
The product of this effort will be a GIS tool that can be used to:

1. Estimate and compare the volume of habitat available for juvenile salmonids at five discharges on the Stanislaus River
2. Evaluate proposed discharge requirements for juvenile salmonids
3. Relate changes in discharge to changes in instream salmonid production potential or other index (i.e. fry to smolt survival).
4. Assist managers and stakeholders in the development of a flow prescription for the LSR.

3.4 Hierarchical Approach

This study proposes a hierarchical approach to "scale up" the discharge to habitat relationship to the entire LSR (Figure 2). We will accomplish this by describing microhabitat use and selectivity by anadromous salmonids, estimating the availability of preferred microhabitat positions within different mesohabitat types, and calculating the total useable habitat available at five different discharges using a combination of hydraulic modeling, GIS analysis, and field mapping of mesohabitats in the LSR.

Figure 2: Illustration of the hierarchical approach to "scale-up" from microhabitat selection of individual fish to an estimate of total useable habitat in the LSR at five discharges.



3.5 Microhabitat Parameters (DEP, VEL, SHE, DCP, DTB)

We will describe microhabitat selection with five parameters: depth (DEP), water velocity (VEL), micro-shear (SHE), distance to cover from predation (DCP), and distance to bank (DTB).

1. Depth (DEP): Water column depth, (cm) at the observed fish position.

2. Velocity (VEL): Water velocity (m/sec) at the observed focal position of the fish (i.e. focal velocity).

3. Micro-Shear (SHE): Water velocity (m/sec) at three radial positions around the focal position of the fish (i.e. feeding velocities at 3, 9, and 12 o'clock positions around the focal position). We are assuming a drift feeding juvenile salmonid chooses the position that maximizes its net energy intake rate (Hughes and Dill (1990)). 'Micro' is used as a prefix in this case to distinguish this type of shear from meso-scale shear provided by hydraulic modeling (see Habitat Variables and Interface of Hydraulic Model and GIS). Micro-Shear is described in further detail in Sidebar 3.

4. Distance to cover from Predation (DCP): Distance (m) to the closest submerged structure that the observed fish

1.1.1 Sidebar 3 - Velocity Shear (Micro-Shear)

Velocity shear (SHE) is the difference in velocity between two points in the river divided by the distance between them:

$$SHE = (V_1 - V_2)/d$$

where,

SHE = velocity shear ($cm \cdot s^{-1} \cdot cm^{-1}$),
V_1 = focal velocity at anterior end of fish ($cm \cdot s^{-1}$), and
V_2 = feeding velocity (maximum water velocity within 2 body lengths (BL) of the fish).
d = distance between points (cm)

Velocity shear is a measure of the quality of a microhabitat location. High SHE allows a fish to swim at a relatively low velocity and feed at a relatively high velocity. For example in the Green River, UT, the larger the rainbow trout the higher value of the SHE at which it tends to be found (Bowen, 1996) and the greater the surplus power (energy per unit time available for growth and reproduction) acquired by the fish.

In the present study, we will use SHE as a measure of surplus power available to a fish at a particular microhabitat position. Surplus power, as defined above, is directly proportional to evolutionary fitness (Ware, 1982).

So we will use SHE, we discuss other parameters below, to define in part the energetic quality of a microhabitat position in two ways: 1) microhabitat locations where the fish are observed and 2) available microhabitat within mesohabitat types. For 1) we will observe the fish, and measure focal velocity (V_1) and SHE at the fish's location. For 2) we measure V_1 and SHE in 40 positions (two locations in the water column at each position) and use the distribution of the 80 observations of S to describe the overall energetic quality of a mesohabitat, i.e. the higher the average S in a mesohabitat the higher the overall energetic quality of that mesohabitat to fish.

We recognize that steelhead and Chinook juveniles are not only trying to find and use energetically advantageous positions with high SHE. We believe the quality of a position is discounted at a rate proportional to the Distance from Cover from Predation (DCP). Thus, we will measure DCP and Distance To Edge (DTE) to assist in defining the most attractive microhabitat sites to juvenile salmonids.

could utilize to escape a piscine (i.e. fish) predator.

5. Distance to Edge (DTE): Distance (m) to the closest feature that intersects with the water surface (e.g. gravel bar, bank, mid channel large woody debris (LWD))

3.6 Mesohabitat Types

The proposed field based habitat classification system is intended to be biologically significant to juvenile salmonids and capable of being generated by a model. Six mesohabitat types are proposed based on three water velocity categories and two categories for distance to edge (Table 1). These parameters can also be acquired by remote sensing and will allow 100% of the river to be mapped at five discharges.

Table 1 Mesohabitat Classifications

Velocity	No Edge (>2m)	Edge (<2m)
Low (<0.15 m/sec or <0.5 ft/sec)	Low Velocity / No Edge	Low Velocity / Edge
Medium (0.15 m/sec - 0..61 m/sec or 0.5 – 2.0 ft/sec)	Medium Velocity / No Edge	Medium Velocity / Edge
High (>0.61 m/sec or >2.0 ft/sec)	High Velocity / No Edge	High Velocity / Edge

3.6.1 Water Velocity Categories

The three velocity categories were selected: low, medium, and high. We based these categories on swimming capabilities and existing habitat suitability curves for 0+ Chinook salmon. We assessed prolonged swimming speeds for Chinook fry using FishXing software by Firor et al, (2006) to determine appropriate velocity categories. For Chinook salmon (TL range 35 mm – 41mm), the prolonged swimming speed ranged from 0.14 m/sec – 0.305 m/sec (0.46 ft/sec – 1.00 ft/sec) (Kerr (1953), Smith and Carpenter (1987)).

We also investigated existing Stanislaus River habitat suitability curves by Aceituno (1990). For 0+ Chinook salmon, approximately 50% probability of use occurs in water velocities less than 0.15 m/sec (0.5 ft/sec) and 100% probability of use occurs in water velocities less than 0.61 m/sec (2.0 ft/sec). For 1+ Chinook salmon, approximately 50 % probability of use occurs in water velocities less than 0.61 m/sec (2.0 ft/sec).

Assumption – Categories were made for 0+ O mykiss and 0+ and 1+ Chinook salmon. If the GIS is used for 1+ *O. mykiss* the user should realize the mesohabitat definitions may not reflect varying degrees of usability based on physiological capacity of 1+ *O. mykiss*.

3.6.2 Edge Categories

We are defining edge as any point where the water surface intersects with an object. We think that proximity to edge is important whether instream or bank. For this study an edge may be a feature at any position in the channel (e.g. gravel bar, bank, or LWD). Because proximity to edge is important, we chose to demarcate edge habitats throughout the LSR. We chose 2 meters as the zone of influence around edge habitat. This distance was chosen because based on observations by Allen (2000) that found less than 1% of Chinook fry observations were of individuals greater than 2 meters (6-10 ft) from a bank. So, we will classify mesohabitats by their proximity to an edge feature. "Edge" mesohabitats are < 2 m from an edge feature while "no edge" mesohabitats are > 2 m from an edge feature.

We originally proposed to use distance to cover from predation (DCP), however, DCP cannot be acquired by remote sensing. We believe that DTE will be a good surrogate for DCP. We will measure both these variables in mesohabitats (during Mesohabitat Availability surveys) and test to see if a correlation exists.

3.6.3 Other Considerations

The main mesohabitat classification system describes the presence or absence of edge features. However, the type of edge or cover feature may be very important. For example, woody debris could be more suitable as cover than a large boulder. We propose to use the following cover code system adapted from (insert reference) to classify edge types:

0 – no edge
1 – bank
2 – undercut bank
3 – overhanging vegetation
4 - rootwad
5 – large wood
6 – non-emergent rooted aquatic vegetation
7 – fine organic substrate
8 – grass
9 – bushes
10 – boulders

These edge types will be identified during field surveys for each mapped mesohabitat. Visual inspection of aerial imagery may also provide additional edge type classification. During field surveys, an estimate of the amount of the observed cover relative to the total size of the mesohabitat will be recorded (0-100%, in 5% increments).

3.7 River Segments

We propose to divide the river into three longitudinal segments (Table 2). For each segment, we will describe microhabitat use of individual fish, determine microhabitat availability within each mesohabitat type, and ground truth 2 linear miles of mesohabitats by field crews.

Table 2 River Segments and Study Reaches

Segment #	Segment boundaries and approximate river mile	Length (miles)	SHUPI Reaches
1	Goodwin Dam (RM 58) to Orange Blossom Bridge (RM 47)	11	Two-mile Bar (0.5 mile) Knights Ferry (0.25 mile) Lover's Leap (0.25 mile)
2	Orange Blossom Bridge (RM 47) to Riverbank (RM 34)	13	Orange Blossom Bridge (0.5 mile) Oakdale (0.5 mile)
3	Riverbank (RM 34) to San Joaquin Confluence (RM0)	34	McHenry (0.5 mile)

4 Developing the Discharge to Habitat Relationship

We will utilize a combination of remote sensing, hydraulic modeling, GIS analysis, and field surveys to estimate the volume of each mesohabitat type at each of five discharges in 100% of the LSR.

4.1 Measuring Habitat Volume

In the Stanislaus River, observations of Chinook parr showed these fish were more likely to use habitats that were over 25 cm deep than habitats less than 25 cm. Also, schools of Chinook parr were larger in deeper water. These anecdotal observations led us to develop methods to estimate mesohabitats volumetrically. If these observations are correct, we think that it is possible for methods that estimate habitat area to systematically underestimate the amount of habitat available.

So, we propose to estimate mesohabitat volume at five discharges by overlaying 2-dimensional (2-D, length and width) mesohabitat polygons on bathymetric (depth) data provided by water penetrating LiDAR. Through the combination of these datasets, we will provide an estimate of how mesohabitat volume changes relative to discharges between 200 and 1500 cfs. We believe that an estimate of habitat volume (3-D) may more precisely describe the amount of available habitat as opposed to a simple area estimate. Kondolf, et al (2001) characterize the lower Stanislaus River as a relatively static and entrenched system with an apparently incised channel. Because large portions of the Stanislaus River channel are incised with trapezoidal channel shapes, changes in discharge between 200 and 1500 cfs may not accurately reveal changes in habitat area. Changes in available habitat may be better represented by estimates that are based on volume.

We will conduct field work at discharges between 200 and 1500. However, the hydraulic model and the LiDAR will make it possible to simulate flows from 1500 to 6000 cfs. The hydraulic model can generate velocities, depths, and distances to edge (DTE) for every cell at every discharge. The distribution of velocities, depths and DTE can be used to extrapolate estimates of habitat volume available at these discharges greater than 1500.

4.2 2-Dimensional Hydraulic Model for Mesohabitats

To assess hydraulic properties, and thus model aquatic habitat at various river discharges, a two-Dimensional (2-D) hydraulic model will be used. Past studies of aquatic habitat have been evaluated with remotely sense data such as hyper-spectral digital photography (e.g. Marcus, 2002 and Marcus et al., 2003) and multidimensional hydraulic models (e.g. Panfil and Jacobson, 2005 and Hilldale, 2007). A distinct advantage of hydraulic models is the ability to obtain many hydraulic variables (such as discrete values of velocity, depth, and Froude number) not available with digital photography. Moreover, obtaining the necessary habitat parameters with a hydraulic model provides the ability to obtain desired parameters at any discharge, where digital photography only provides parameters at the discharge during the time of acquisition.

4.3 Data Acquisition

The terrain input for the 2-D hydraulic model will be derived from a combination of bathymetric LiDAR (Light Detection and Ranging) and terrestrial LiDAR. Bathymetric LiDAR has the capability of obtaining river bottom elevations through the water column and will be used to construct the below-water portion of the terrain model. Terrestrial LiDAR will be used for the above-water portions of the terrain model. Point densities for the bathymetric LiDAR are on the order of 2x2 meters or 1x2 meters, depending on the method of collection. Terrestrial LiDAR is capable of surveying bare earth at a 0.5 x 0.5 meter point densities.

While terrestrial LiDAR has a mature record in the literature (e.g. Brinkman and O’neill, 2000, Bowen and Waltermire, 2002, Charlton et al., 2003), bathymetric

LiDAR as applied to rivers is a relatively young technology. Details regarding the quality of bathymetric LiDAR can be found in Hilldale and Raff (2007). A recent example of using bathymetric LiDAR to construct a 2-D hydraulic model to evaluate aquatic habitat can be found in Hilldale (2007).

4.4 The Hydraulic Model

GSTAR-W (Generalized Sediment Transport for Alluvial Rivers – Watershed) is a finite volume, vertically averaged, 2-D hydraulic and sediment transport model and is the model that will be used on this project. This model takes advantage of a combination structured and unstructured mesh (Lai, 2000). Such a mesh allows varied definition of mesh resolution, which constructs a higher resolution mesh in areas of higher interest and greater topographic variability and a lower resolution mesh in areas of lesser interest and lower topographic variability. A mesh constructed in this fashion provides the necessary detail without sacrificing computational time. The model can also use a more consistent mesh definition when needed. GSTAR-W was developed by Dr. Yong Lai (Lai, 2006) of the Sedimentation and River Hydraulics Group at Reclamation's Technical Service Center. Details regarding the model can be viewed at www.usbr.gov/pmts/sediment. GSTAR-W has been used successfully for several purposes on many projects in Reclamation (e.g. Yakima River, Rogue River at Savage Rapids dam, Yuma River, Sandy River. Sacramento River, Elwha River, Dungeness River. Colorado River, and Rio Grande). A bank of hi-speed (> 2GHz processing speed) desktop computers is available to the modeler, which allows parallel simulations.

4.5 Verification of LiDAR and Model Results

Both types of LiDAR (terrestrial and bathymetric) and the hydraulic model will require verification using field-collected data. Surveys using an Acoustic Doppler Current Profiler (ADCP, manufactured by TRD Instruments) in conjunction with Real Time Kinematic (RTK) Global Positioning Satellite (GPS) surveying equipment will be used to collect water surface elevation, depth, velocity and discharge data. The RTK-GPS surveying equipment will be used alone to collect bare earth elevations. First the LiDAR data will be verified and checked for quality using the field-collected bed and bare earth elevations. The hydraulic model will be verified using water surface elevations, depth, and velocity data collected in the field.

4.6 Habitat variables and Interface of Hydraulic Model with GIS

The hydraulic model will provide the following properties in each computational cell; depth, x-velocity, y-velocity, magnitude velocity, Froude number, water surface elevation. The mesh scale of the hydraulic model will be on the order of 1m x 1m, providing meso-scale features. From these hydraulic properties the following meso-scale habitat features will be determined; magnitude velocity, depth, shear, and distance to edge. Using the distance to edge and magnitude velocity parameters, six meso-habitat types will be determined as shown in Table 1.

Results from GSTAR-W can be directly imported to a Geographical Information System (GIS) for habitat analysis. Point data obtained by the model can be used to generate grids representing various hydraulic properties mentioned above. Most properties can be directly displayed in GIS, such as velocity and depth. Some further computation must be coded into GIS to determine other attributes such as shear and distance to edge.

The list below shows the steps involved in obtaining hydraulically modeled habitat parameters for this project.

1. Fly bathymetric and terrestrial airborne LiDAR and simultaneously obtain digital imagery.
2. Prepare a base map from orthorectified images.
3. Verify the LiDAR with ground surveys collected in the field.
4. With the verified LiDAR, generate a Digital Elevation Model (DEM) that includes the banks, gravel bars, and the wetted channel.
5. Construct and verify the hydraulic model.
6. Run the model at the five desired discharges.
7. Load the results of the 2-D hydraulic model into the GIS:
   a. Layer 1 – depth-averaged magnitude velocity
   b. Layer 2 – depth
   c. Layer 3 – DTE
8. Aggregate pixels with similar velocities and similar DTEs into mesohabitat polygons.

4.7 Ground truth modeled mesohabitats in the LSR

We will ground truth 6 miles (~10%) of the LSR to:
1. Verify mesohabitat classification by the hydraulic model and GIS.
2. Calculate error in mesohabitat size estimates generated by the GIS.

We will compare mesohabitat volumes measured by field crews with mesohabitats generated by the GIS to calculate error estimates on the discharge to habitat figure for each discharge (Figure 3).

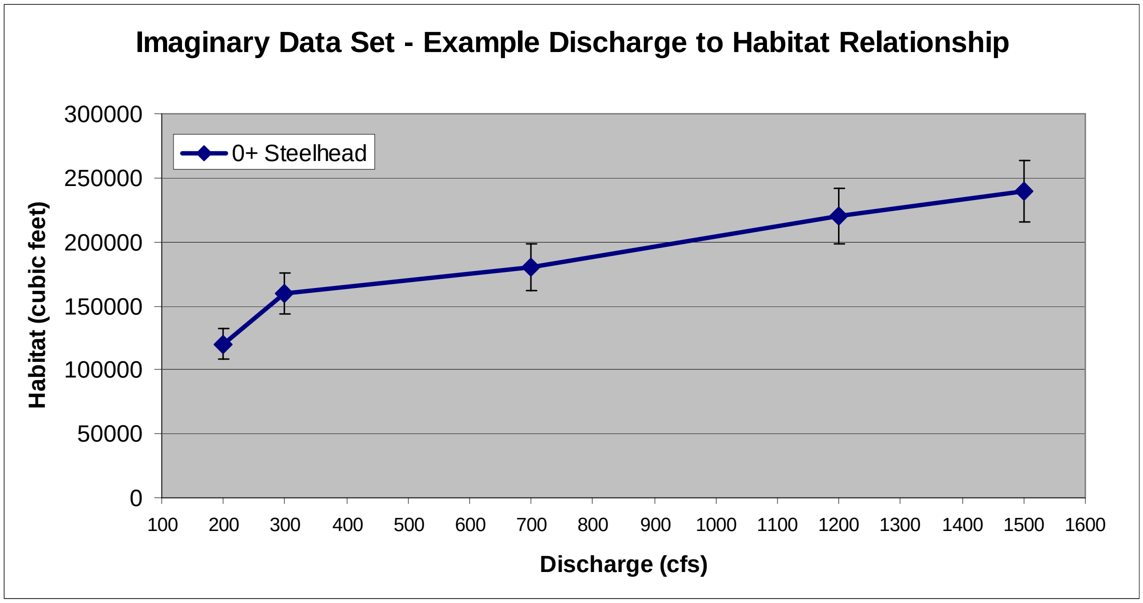


Figure 3: Example dataset showing error estimates for habitat volumes between ground truth and GIS generated mesohabitats.

5 Field Survey Methods

The following sections describe the methods, equipment, and personnel requirements for conducting field surveys.

5.1 Field Survey Crews

Five different field crews are needed to complete the required field work for the Scale-up Study (Table 3).

Table 3 Field crew personnel requirements.

		Crew members
1	Microhabitat Use (MU)	1-2
2	Microhabitat Availability (MA-Boat)	3-4
3	Microhabitat Availability (MA-Foot)	2-3
4	Mesohabitat Ground truth (MG)	4-5
5	Hydraulic Modeling Field Data Collection (HM)	2-3
	Total	12-17

The Microhabitat Use crew will only be required to work during the SHUPI fish surveys at 300 and 1500 cfs. The Hydraulic Modeling Field Data Collection (HM) crew will collect field data to verify LiDAR bathymetry and validate depths and velocities generated by the model with measured field data. Both Microhabitat Availability (MA-Boat and MA-Foot) crews and the Mesohabitat

Ground truth (MG) crew(s) will work at all five discharges. A minimum of nine people will be required for three weeks to collect MA and MG data at each discharge. Additional personnel will be required on the MU crew for surveys at 300 and 1500.

The following sections describe the specific tasks, data requirements, and methods for each of the crews.

5.2 Microhabitat Use (MU)

5.2.1 Objective

Collect microhabitat use data at focal positions for 0+ Chinook salmon, 0+ *O.mykiss*[2], and 1+ *O.mykiss* using five parameters: depth (DEP), velocity (VEL), shear (SHE), distance to cover from predation (DCP), and distance to bank (DTB).

The MU crew requires 1-2 people working in cooperation with a SHUPI snorkeler to collect microhabitat data at precise positions that fish are occupying. Five microhabitat parameters (DEP, VEL, SHE, DCP, and DTB) will be measured at fish focal positions identified by SHUPI snorkel crews. We will attempt to collect 300 positions during the three-week survey effort.

When a fish is observed, the SHUPI snorkeler will record species (Chinook salmon or *O.mykiss*), total body length (in millimeters), and distance from substrate (in centimeters) on a dive slate and place a numbered marker directly below the observed focal position. The unique number on the marker will be recorded on the dive slate to allow multiple positions to be marked before collecting the associated MU data.

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[2] 0+ *O.mykiss* may not be emerged yet during this survey effort. Additional fish observations may need to be conducted at a later date to capture all life history stages.

Figure 4: Microhabitat Use crew collecting measurements at marked microhabitat positions.

Once several positions are marked, the MU crew will visit each marked location with the snorkeler. The MU crew will use a Trimble GPS to record the data collected by the snorkeler (marker number, species, length, and distance to substrate). Next, the MU crew will collect data for the following five parameters:

1. Depth (DEP): Water column depth, (cm) at the observed fish position.
2. Velocity (VEL): Water velocity (ft/sec – 10 second average) at the observed focal position of the fish (i.e. focal velocity).
3. Shear (SHE): Water velocity (ft/sec – 10 second average) at three radial positions around the focal velocity (i.e. feeding velocities at 3, 9, and 12 o'clock positions around the focal position). SHE is described in Sidebar 3).
4. Distance to cover from Predation (DCP): Distance (m) to the closest submerged structure that the observed fish could utilize to escape a piscine (i.e. fish) predator.
5. Distance to Edge (DTE): Distance (m) to the closest edge feature in the river channel.

5.3 Microhabitat Availability (MA)

5.3.1 Objective

Collect microhabitat availability data within each of the mesohabitat types in each of the river segments. Forty points will be collected within each of the six mesohabitat types in each of the three river segments. Therefore a total of 720 point locations will be collected at each discharge (40 x 6 x 3 = 720). Replicate data will be collected if time allows.

Microhabitat Availability data will be collected by two different crews: one crew working on foot (MA-Foot) in shallow water habitats and another crew working from a jet-boat in deep water habitats (MA-Boat). Both crews will collect the same data but will utilize different equipment.

5.3.2 MA-Foot Crew

The MA-Foot crew will require 2-3 people (1-2 data collectors and 1 data recorder) to work in shallow water margin habitats. The MA-Foot crew will also be equipped with a kayak to effectively sample deeper portions of shallow water habitats.

5.3.3 MA-Boat Crew

The MA-Boat crew will require 3 people (1 certified boat operator, 1 data collector, and 1 data recorder) to work in deep water habitats (Figure 5). Reclamation's jet-boat is equipped with 5 davits and a multi meter mount (velocity array) to allow for efficient sampling of deep water habitats. The velocity array was designed to improve the accuracy and efficiency of focal and feeding velocity measurements. The velocity array consists of attachments for up to four velocity meters that can be operated simultaneously (see Appendix C for photos). The array is attached to a lead weight to allow measurements at any point in the water column.

Figure 5: Microhabitat Availability boat crew collecting data in mid-channel mesohabitat, July 2006.

The data requirements will be the same for both MA crews. Within each mesohabitat type, a total of 40 points will be surveyed (Appendix D – Minimum Sample Size Analysis). These points will be selected using a systematic sampling design with a random start. At each point, five microhabitat parameters (DEP, VEL, SHE, DCP, and DTE) will be measured.

5.4 Mesohabitat Mapping – Ground Truth

5.4.1 Objective

Ground truth model generated mesohabitats on the LSR at all discharges by field surveys. The goal is to map 10% of the river (6 miles, 2 in each segment) using the following process:

5.4.2 Rules for Delineating Mesohabitat Types

The following rules were developed to help standardize the classification and delineation of mesohabitat types and be consistent with mesohabitat classifications generated by the GIS and hydraulic model:

1. Lateral boundaries for edge habitats will extend 2 m from the edge feature.
2. Upstream and downstream (longitudinal) boundaries of a mesohabitat will be delineated by water velocity (Low, Medium, or High). Boundaries will

be at obvious velocity breaks. For example, between a pool and riffle where laminar flow transitions to turbulent flow or when a velocity transitions across one of the thresholds between velocity categories.

3. Boundaries between adjacent mesohabitats are approximately 1 m wide and 0.5 m of this lies within each adjacent mesohabitat.
4. For any given lateral transect, the river will be delineated into a minimum of two margin habitats (i.e. edge) and one mid-channel habitat.
5. Lateral mid-channel habitats will be set by default at the edge of the margin habitat.
6. Edge habitats may be present in mid-channel if a feature intersects with the water surface.

5.5 Hydraulic Modeling Field Data Collection

Methods for validating both LiDAR data and the hydraulic model are provided in Section 4.5.

5.6 Global Positioning System Units

Trimble® GeoExplorer® 2005 series GPS units (Models GeoXT™ and GeoXH™) will be used to collect field survey data. These units provide sub-meter accuracy after correction. Proposed data dictionary definitions for each field crew are provided in Appendix E.

6 Study Coordination

The proposed effort requires involvement of multi-disciplinary team members to develop a product that is capable of meeting the needs of Reclamation and Stanislaus River stakeholders. In addition, this effort can substantially benefit from the continued participation of regulatory agencies, resource agencies, water purveyors, and others with interest in the Stanislaus River.

Reclamation intends to continue efforts to coordinate the development of this study design and develop partnerships with stakeholders to develop a suitable tool to evaluate discharge requirements for juvenile salmonids and aid in the development of a flow prescription for the Stanislaus River.

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Appendixes

Appendix A – S&T Proposal

I. General Information | II. Product Description | III. Proposed Steps | IV. Funding Request
V. Partners | VI. Advocates | VII. Beneficiaries | VIII. Project Team | IX. Technical Reviewers
X. Comments | XI. Team Qual. | XII. Progress and Plans

ID: 7899 - Saving Water and Insuring Delivery: Flow Prescription and the Discharge to Habitat Relationship for a Listed Anadromous Salmonid

Submitted by: Mark Bowen, Fisheries Applications Research Group, 86-68290, 303.445.2222, mbowen@do.usbr.gov

I. General Information

A. Title (250 character limit including spaces)
Enter a title and then click "Update Title".

Saving Water and Insuring Delivery: Flow Prescription and the Discharge to Habitat Relationship for a Listed Anadromous Salmonid

B. State the question your R&D would answer.
(Please do not disclose any potential intellectual property in this section. See Section I.F below. 1000 character limit including spaces)

Can we save water by agreeing with regulatory agencies about how much water to deliver for fisheries? Can we base our flow prescription on precise science: the relationship between discharge(Q) and habitat for listed steelhead?

Reclamation is required by law to enhance fisheries using the best available science and to reduce dependency on New Melones water. As a response to this requirement Reclamation is working to develop a Flow Prescription (FP) in a river inhabited by two important anadromous salmonid species: listed steelhead and Fall Chinook. The FP could be guessed at now but would not be precise. So, more water would be delivered for instream flows than perhaps is necessary. Generating a more precise predictive function of habitat that is provided by various Q's will allow Reclamation to save water by releasing what is necessary and sufficient for fishes. The balance may be stored for delivery for power generation, irrigation, and other environmental needs.

C. R&D Focus and Output Areas

WD2-Reduce Ecosystem Impacts on Water Delivery
WD2

D. Proposed Start and Completion Years
Select proposed start and completion years, then click "Update Years".

Proposed Start Year FY: 2007

Proposed Completion FY: 2010

E. Type of Proposal (pick one)
Select the type of proposal you are submitting, then click "Update Type"

○ Scoping or Formulation (Should not exceed $10,000 to $15,000)

◉ Conducting research and development.

F. Security and Intellectual Property Alert: If Sections II and/or III below contain information that could be considered propriety or potentially patentable please check "yes" below. Be sure to note that if you check "yes", reviewers of your proposal will sign a non-disclosure agreement. The Title and R&D Question, Sections I.A and I.B, will not be protected and should be worded such that potential intellectual property is not disclosed. Make a choice below, then click "Update Alert".

○ Yes

◉ No

If you answered Yes, reviewers of your proposal will sign a non-disclosure agreement. The information in Section I will not be protected and should be worded such that potential intellectual property is not disclosed.

II. Proposed Research End Products, Completion Dates, Need, and Benefit

The R&D end product is the tool, solution, practice, device, etc. that your R&D is proposing to produce. To specify the end product(s) of your R&D, begin by clicking on "Add New End Product". You can select the general category for your R&D end product(s) from a pull-down menu, use the text box to further describe your end product, enter the completion date, and select the way in which your end product(s) will be documented from a pull-down menu. In order to specify R&D end product(s), you must select an R&D Output Area in Section IC. You can describe up to three end products.

Past due products will be highlighted in yellow. Products received by the Research Office will be highlighted in green.

A. No.	**R&D End Product Category**	**How will your end product (s) be documented**	**Scheduled Completion Date**
1	Tools to offset or reduce impacts on water projects due to environmental constraints Geographical Information System that Delineates the Discharge-Habitat Relationship at Five Discharges for Juveniles of: 1. Fall Chinook and 2. Listed Steelhead	Report	09/30/2010

B. Need and Benefit
Describe existing capabilities available to Reclamation from both internal and external sources. Explain why they are insufficient to adequately serve Reclamation's needs. (4000 character limit including spaces)

Need - Reclamation must develop a Revised Plan of Operations (RPO) for New Melones Dam. And New Melones releases determine lower Stanislaus River (LSR) discharge. Public Law 108-361 directs that actions to enhance fisheries in the Stanislaus River are based on the best available science. As part of this effort, Reclamation is developing the biological basis for the Flow Prescription (FP). The Stanislaus FP will prescribe a flow schedule (on a monthly or weekly time step) that varies with water year type. This effort will provide a Microhabitat-Explicit GIS (MEG) that will help Reclamation determine, with stakeholders and regulatory agencies, what instream discharge is appropriate for fall run Chinook salmon (CS) and federally listed steelhead (SH) in the LSR.

Benefit - As part of the New Melones RPO, the FP will provide benefits to Reclamation, water users, and regulatory agencies by specifying instream discharge requirements: Reclamation can plan the facilities and operations necessary to meet the FP and the multiple other demands in the system, water users will know early in the year (based on that year s hydrologic forecast) how much water they will receive in that year, and regulatory agencies will receive flows capable of producing a sustainable fishery. Thus, the benefits of this study include: improving Reclamation operations efficiency, insuring water delivery and reliability, and assuring instream flows that will contribute to the potential de-listing of SH while avoiding the possible listing of CS.

Need - The need to save water that otherwise might have been released unnecessarily provides our principal objective: determine the discharge-habitat relationship sufficiently to write a precise FP.

Benefit - An important benefit of this research will be the water saved by a precise FP. How much water will this be? It is impossible to determine at this time. One example could be: If discharge in a Dry Year were reduced from 250 to 235 cfs during the irrigation season, this would result in 4,522 AF of water saved. The value of this water ($125/AF) over a 4-year period is $2,261,157. Total requested funds from S & T is $160,000 over 4 years. S & T s return on its research investment would be more than $14 to every $1.

Need - Reclamation needs to develop a way to predict the discharge necessary to provide habitat throughout an entire river. In several cases, Reclamation possesses subsampled habitat units in rivers. There has been minimal Reclamation effort to date using GIS, to devise a method to "scale up" these subsamples to an entire river. Reclamation efforts have used IFIM methods with significant assumptions about limiting factors, independence of independent driving variables, and the position where water velocity is normally measured (6/10th of the water column) is seldom where the fish are found.

Benefit - This research effort will develop a new method (MEG) for scaling up subsampled habitats to a discharge-habitat relationship for an entire river. If S&T provides matching funds to do this, the benefits can be used Reclamation-wide to predict habitat available at different discharges. To be clear, in each river system new information will have to be collected, e.g. photographic imagery at the discharges at which habitat will be predicted. But, this new MEG we are proposing to develop can be used to scale up the subsampled habitats using imagery. Thus, a manager could direct biologists to use the MEG to develop discharge-habitat relationships in any river where sufficient subsampled habitat data exists.

C. Why is this the responsibility of Reclamation and not another government agency or the private sector. (3000 character limit including spaces)

Reclamation is required by law (Public Law 108-361) to enhance fisheries using the best available science and to reduce dependency on New Melones water for fisheries. As one response to this requirement Reclamation is working to develop a Flow Prescription (FP). First then, the need and responsibility for this research is set forth by law. To develop a precise FP, understanding of the relationship between discharge and habitat is required; the more precise the FP the more water that will be saved because you only deliver the water necessary.

Second, Reclamation also has responsibility to irrigators, municipalites, and other water users to deliver water. The FP will provide written documentation of what water availability will be in each water year type. Therefore, water delivery will be insured for the water users.

Third, Reclamation's mission specifies we shall manage, develop, and protect water resources in an environmentally and economically sound manner. This directive compels us to save water where possible but also to provide sufficient water to protect fisheries downstream of our facilities. Thus Reclamation has a responsibility to produce a FP through consultation with regulatory agencies that will protect important water resources such as threatened steelhead and economically-important Fall Chinook salmon.

III. Proposed Steps to Produce the R&D End Products Listed in Section II

This is your work plan. You will use your work plan to track your progress on this project. This work plan will also be used to demonstrate to reviewers that you have a sound, responsible, and cost appropriate plan to undertake the R&D project.

A. Briefy Describe: i. The methods and approaches you will use to answer your research question and ii. How you will share your research end product with peers and stakeholders. (4000 character limit including spaces)

A. First, we will acquire data from the Stanislaus Habitat Use Pilot Investigation(SHUPI): 1. 2D modeling at two 0.25-mi study reaches. 2. Habitat information and a fish survey at two Q's (Q=discharge) (300 cfs, Feb 2007, and 1500 cfs, May 2007): a. mapped mesohabitat (e.g. riffle) polygons in a GIS for seven study reaches (0.5-mi long study reaches that will be surveyed). b. fish density data for each mesohabitat.

B. For each mesohabitat type determine the frequency distributions of depth (DEP), velocity (VEL), velocity shear(SHE-difference in feeding velocity and focal velocity divided by the distance between(See Section 10)) and DCP(distance to cover from predation). Develop these frequency distributions at the five experimental Q's: 200, 300, 700, 1200, and 1500 cfs:

1. At 1200 cfs, July 17 2006, preliminary data were acquired: DEP, VEL, SHE, and DCP in sites specified in A.1.

2. Using these preliminary data and estimates of variance, we will conduct a sample size required analysis to determine N. N is the number of points that must be sampled to adequately depict the depth (DEP) distribution in each mesohabitat type. Repeat these analyses for VEL, SHE, and DCP.

3. For every mesohabitat type, we wish to determine the microhabitat availability of DEP, VEL, SHE, and DCP. To accomplish this, we will randomly select three (3) mesohabitat representatives of each type. For each mesohabitat representative, we will systematically collect N observations for DEP, VEL, SHE, and DCP. We will determine the frequency distribution of all four microhabitat variables in each mesohabitat at each of the five experimental Q's; this is the Microhabitat Availability (MA) data set.

C. For each species and life stage of interest (Chinook fry, steelhead 0+, and steelhead 1+), generate preference curves for each of these 4 variables, DEP, VEL, SHE, and DCP:

1. Follow SHUPI snorkeling teams, and at the location of each fish counted collect the following data: DEP, VEL, SHE, and DCP. This is the Microhabitat Use (MU) data set.

2. With the MU and the MA data sets, calculate preference similar to Chesson(1983).

D. Determine the total volume and relative proportion of the mesohabitat types in the entire river at each of the five experimental Q's. Through aerial photos and ground surveys, determine how much of each mesohabitat type there is in the lower Stanislaus River (LSR).

E. Determine the relative proportion of each mesohabitat to the total habitat available in the LSR. Then, we will calculate what amount of that mesohabitat type that will actually be used. Finally, we will sum all habitat use across mesohabitat types to determine total usable habitat at each experimental Q. One of the central objectives of this study is determine how to calculate what amount of a particular mesohabitat type will be used. Some methods are known to us, e.g. PHABSIM (Bovee and Cochnauer, 1977) and logistic regression(e.g. Tiffan, 2002). We will evaluate each of the possible approaches and determine which is the most advantageous to use in this application. If we find none will work, we will develop a new technique.

The objective, determining how to calculate the amount of a particular mesohabitat that will actually be used, is the primary research contribution we will make. The principal application will be to determine the relationship of Q (range of 200 to 1500 cfs) to habitat for species and life stages of interest.

We will provide the complete GIS to stakeholders and peers; it can be used to complete many other analyses than just the ones provided by us. Most importantly the GIS can be used to formulate a precise Flow Prescription; saving water and insuring delivery. We will also provide a report that describes the GIS, our analyses, and the discharge-habitat relationship for each species and life stage of interest.

List the sequential steps that you will take to conduct your R&D and share the results with end users and peers to promote adoption of your research end product. Enter the steps in the table below that you will use to produce the research end product listed in Section II.

B. No.	Proposed Steps To Produce the Research End Products Outputs listed in Section II (Each Task description is limited to 400 characters but there is no limit on the number of tasks you can enter.)	Requested S&T Budget for Each Step	Scheduled Completion Date
1	Coordinate with stakeholder groups and regulatory agencies	$1,456.00	12/15/2006
2	Conduct Required Sample Size Analysis with preliminary estimates of variance	$1,145.00	01/15/2007
3	Acquire digital orthrectified imagery of the LSR with at least 2 foot resolution at 2 discharges	$1,876.00	03/01/2007
4	Conduct microhabitat use and availability field work at 300 cfs	$10,504.00	03/31/2007
5	Conduct microhabitat use and availability data at 1500 cfs	$8,344.00	06/30/2007
6	Test fish density data acquisition methodologies in the turbid lower Stanislaus River(LSR)	$1,400.00	08/31/2007
7	Conduct a ground survey of all areas unseen (e.g. by vegetation) by multispectral imagery and bathymetric methods to GPS wetted edge, take depth measurements, and draw mesohabitat polygons at 1 Q	$9,085.00	08/31/2007
8	Literature review of habitat preference for juveniles of: 1. chinook salmon and 2. threatened steelhead.	$2,436.00	09/28/2007
9	Literature review of microhabitat use probability functions (i.e. what research has been conducted that determines the probability a fish will use a particular microhabitat position)	$3,062.00	09/29/2007
10	Evaluate methods to acquire bathymetry data of the LSR at 5 discharges	$2,009.00	09/30/2007
11	Project Management	$2,912.00	09/30/2007
12	Coordinate with stakeholder groups and regulatory agencies	$1,456.00	12/15/2007
13	Acquire bathymetric data for the LSR at 5 Q's	$1,281.00	01/30/2008
14	Acquire digital orthrectified imagery of the LSR at 2 Q's	$3,173.00	03/01/2008
15	Conduct microhabitat use and availability field work, 200 cfs	$10,168.00	03/31/2008
16	Conduct microhabitat use and availability field work, 700 cfs	$8,008.00	06/30/2008
17	Obtain microhabitat use data in turbid LSR at 2 Q's	$3,500.00	07/01/2008
	Conduct a ground survey of all areas unseen (e.g. by vegetation) by		

18	multispectral imagery and bathymetric methods to GPS wetted edge, take depth measurements, and draw mesohabitat polygons at 2 Q's	$7,410.00	08/30/2008
19	Create a basemap for 2 Q's	$4,534.00	09/29/2008
20	Project Management	$2,912.00	09/30/2008
21	Coordinate with stakeholder groups and regulatory agencies	$1,456.00	12/15/2008
22	Create depth layers from bathymetric data at 5 Q's	$5,644.00	01/15/2009
23	Acquire digital orthrectified imagery of the LSR at one Q	$417.00	03/01/2009
24	Conduct microhabitat use and availability field work, 1200 cfs	$8,043.00	03/15/2009
25	Input mesohab data to create layers at 3 Q's	$4,101.00	03/30/2009
26	Obtain microhabitat use data in turbid LSR at 2 Q's	$3,500.00	07/01/2009
27	Conduct a ground survey of all areas unseen (e.g. by vegetation) by multispectral imagery and bathymetric methods to GPS wetted edge, take depth measurements, and draw mesohabitat polygons at 1 Q	$7,410.00	07/02/2009
28	Create a basemap for 2 Q's	$4,170.00	07/15/2009
29	Input microhabitat data (Velocity etc) into layers	$2,085.00	07/30/2009
30	Input fish density data into layers at 3 Q's	$2,085.00	07/31/2009
31	Calculate the amount of each mesohab at 2 Q's	$834.00	08/15/2009
32	Calculate the relative amount of each mesohab at 2 Q's	$834.00	09/29/2009
33	Project Management	$2,912.00	09/30/2009
34	Coordinate with stakeholder groups and regulatory agencies	$1,456.00	12/15/2009
35	Input mesohabitat data to create layers at 2 Q's	$1,042.00	03/30/2010
36	Obtain microhabitat use data in turbid LSR at one Q	$2,100.00	03/31/2010
37	Conduct a ground survey of all areas unseen (e.g. by vegetation) by multispectral imagery and bathymetric methods to GPS wetted edge, take depth measurements, and draw mesohabitat polygons at one Q	$3,703.00	07/01/2010
38	Create a basemap for one Q	$1,251.00	07/05/2010
39	Input fish density data into layers at 2 Q's	$2,085.00	07/10/2010
40	Calculate the amount of each mesohabitat at 3 Q's	$834.00	07/13/2010
41	Calculate the relative amout of each mesohabitat at 3 Q's	$834.00	07/14/2010
42	Populate mesohabits with microhabit data from representitive mesohabitats	$1,668.00	07/15/2010
43	At Each Q, Calculate the Probability of Use for each cell for O.mykiss 0+	$5,213.00	08/01/2010
44	At Each Q, Calculate the Probability of Use for each cell for O.mykiss 1+	$3,127.00	08/15/2010
45	At Each Q, Calculate the Probability of Use for each cell for Fall Chinook 0+	$3,128.00	09/01/2010
46	Total the Amount of Habitat Present for each Species and Life Stage at Each Q	$4,170.00	09/15/2010
47	Port GIS to CCAO and instruct personnel, stakeholders, and regulatory agencies in its use	$2,862.00	09/29/2010
48	Prepare Final Report	$8,146.00	09/30/2010
49	Project Management	$2,912.00	09/30/2010
Total Funding		$174,693.00	

IV. Fiscal Year S&T Program Funding Request

Fiscal Year	Funding Requested

2007	$44,229.00
2008	$42,442.00
2009	$43,491.00
2010	$44,531.00
Total Requested S&T Funding	$174,693.00

Note: Once a multiyear proposal is funded, it will be evaluated each year for the merit of continuation of funding. Accomplishing prior year tasks will be a key consideration. Commitment of funding other than current year is subject to appropriations.

V. Partners - Cost-Sharing With Others Who Have A Stake in This Effort

Enter a list of cost share partners in your R&D. By entering a partner below you are affirming that person has been briefed on this R&D proposal and has agreed to cost-sharing. The Research Office may contact partners for further information.

No.	Partner First Name	Partner Last Name	Organization	Phone	E-mail	Firm or Potential	Inside or Outside
1	Brian	Deason	CC-415(Folsom Area Office)	916-989-7173	bdeason@mp.usbr.gov	Firm	Inside
2	Andrew	Hamilton	US Fish and Wildlife Service	916-414-6540	Andrew_Hamilton@fws.gov	Firm	Outside
3	Tim	Heyne	California Department of Fish and Game	209-853-2533	theyne@dfg.ca.gov	Firm	Outside
4	Tim	O'Laughlin	Tri-Dam Project (Consortium of Irrigation Districts)	530-899-9755	TOLaughlin@olaughlinparis.com	Firm	Outside

You must add the partner above before you describe the contribution below.

No.	Partner Last Name	Description of Partner Contribution	Cash / IKS	Year	Projected Contribution Value
1	Deason	Will pay for all field equipment, remote sensing, and time of all CA participants.	Cash	2007	$120,000.00
2	Deason	Will pay for all field equipment, remote sensing, and time of all CA participants.	Cash	2008	$123,000.00
3	Deason	Will pay for all field equipment, remote sensing, and time of all CA participants.	Cash	2009	$126,075.00
4	Deason	Will pay for all field equipment, remote sensing, and time of all CA participants.	Cash	2010	$129,227.00
5	Hamilton	Will provide field assistance and data/document review	IKS	2007	$3,000.00
6	Hamilton	Will provide field assistance and data/document review	IKS	2008	$3,000.00
7	Hamilton	Will provide field assistance and data/document review	IKS	2009	$3,000.00

8	Hamilton	Will provide field assistance and data/document review	IKS	2010	$3,000.00
9	Heyne	Will provide field assistance and data/document review	IKS	2007	$3,000.00
10	Heyne	Will provide field assistance and data/document review	IKS	2008	$3,000.00
11	Heyne	Will provide field assistance and data/document review	IKS	2009	$3,000.00
12	Heyne	Will provide field assistance and data/document review	IKS	2010	$3,000.00
13	O'Laughlin	Will provide biologist for field assistance and data/document review	IKS	2007	$3,000.00
14	O'Laughlin	Will provide biologist for field assistance and data/document review	IKS	2008	$3,000.00
15	O'Laughlin	Will provide biologist for field assistance and data/document review	IKS	2009	$3,000.00
16	O'Laughlin	Will provide biologist for field assistance and data/document review	IKS	2010	$3,000.00

VI. Advocates - List Reclamation Managers, Other Stakeholders, and Project Output Beneficiaries That Advocate this Proposed Effort

Enter a list of advocates for your research. By entering an advocate below you are affirming that person has been briefed on this R&D proposal and indeed advocates it. The Research Office may contact advocates for further information. To start building a table of advocates, click the Add New Advocate link. For each additional advocate, click Add New Advocate again.

First Name	Last Name	Title	Organization	Phone	Email
Mike	Finnegan	Area Manager	CC-100	916-989-7267	mfinnegan@mp.usbr.gov
Trevor	Kennedy	General Manager	Fisheries Foundation of California	209-649-8914	cosumnes@comcast.net
Scott	Kline	Fisheries Biologist	YAK-5003	509-575-5848	skline@pn.usbr.gov

VII. Research Beneficiaries and R&D Locations

A. Primary Research Beneficiaries

Region 1	Region 2	Region 3
BOR-WIDE	MP	PN

B. R&D Location

Indicate whether your R&D is field, office, or laboratory based. If your R&D is field based, select the Reclamation Area Office whose boundaries include the area of your fieldwork. Also for field based R&D, list the primary field contact.

Field/Office/Lab Based	Area Office	Primary Field Contact
Field based	Central California	Brian Deason, bdeason@mp.usbr.gov CC-415

C. NEPA Compliance Contact

Applies to field-based proposed R&D. A Categorical Exclusion Checklist, or other appropriate NEPA document or permit, must be completed before field activities begin. Who is, or will be, responsible for completing a Categorical Exclusion Checklist or other NEPA compliance document?

First Name	Last Name	Organization	E-mail	Location of NEPA Document
Brian	Deason	Reclamation CCAO	bdeason@mp.usbr.gov	Folsom, CA CCAO

VIII. Project Team

List the team members that would participate in the proposed R&D.

First Name	Last Name	Discipline/Speciality	Organization	Phone	E-mail	PI
Dr. Mark	Bowen	Fisheries Biology/Biostatistics/Mathematical Modeling	86-68290 (was D-8290)	303-445-2222	mbowen@do.usbr.gov	Yes
Brian	Deason	Fisheries Biology	CC-415	916-989-7173	bdeason@mp.usbr.gov	No
John	Hannon	Fisheries Biology	MP-150	916-978-5524	jhannon@mp.usbr.gov	No
Ron	Sutton	Physical Habitat Modeling in Rivers	86-68210 (was D-8210)	303-445-2495	rsutton@do.usbr.gov	No
Dr. Katherine	Zehfuss	GIS/Fisheries Modeling	86-68290 (was D-8290)	303-445-2240	kzehfuss@do.usbr.gov	No

IX. Potential Technical Reviewers

Enter the names and contact information for three technical reviewers outside of Reclamation that are qualified to review your research proposal. Please enter a list of keywords that describe the expertise of the potential technical reviewer.

First Name	Last Name	Field of Technical Expertise	Key Words Associated with Potential Reviewer's Expertise	Affiliation	Phone	E-mail

Kenneth	Tiffan	Fish Habitat Assessment/Fish Migratory Behavior	No key words yet	USGS-Cook, WA	509-538-2299	ken_tiffan@usgs.gov
Peter	Baker	Mathematical Biology/Biostatistics/Fish Population Biology	No key words yet	Stillwater Sciences, Private Consulting Firm, Berkeley, CA	510-848-8098	pfb@stillwatersci.com
John	Williams	Fluvial geomorphology/Salmonid Biology/Instream Flow Assessment	No key words yet	Independent Private Consultant	530-753-7081	jgwill@dcn.davis.ca.us

X. Comments and Additional Information

Comments and Additional Information
Use this space to provide any additional inforamtion regrading this proposed effort (4000 characters limit including spaces)

Notes on Methods

1. How to determine feeding velocity and calculate velocity shear(SHE)? First, we will identify a Reaction Distance (RD). In February, the length category for Fall Chinook with the highest frequency of fish is 40-60 mm (Stanislaus Snorkel Survey Data, 2003 and 2005). In May, age 0+ O. mykiss are in the 40 - 50 mm length category. We have decided to use a RD of 2 Body Lengths (BL). This is the upper limit of RD found for 40 mm coho (Dunbrack and Dill, 1983) (other workers have published values ranging around this: 1.5 - 2.8 BL (Hughes and Dill, 1990)). Therefore we will assume that for 50 mm salmonids feeding on large prey the RD is 100 mm. Second, we will measure four velocities on a circle centered about the focal point of the fish. The circle will have a radius of 100 mm simulating the feeding window of the fish. The fastest velocity among these four velocities surrounding the focal point will be the feeding velocity (FED). And velocity shear can be calculated as SHE = (FED - VEL/d) where VEL is the velocity at the focal point and d is the distance between FED and VEL.

2. Microhabitat Explicit GIS (MEG) contrasted with IFIM.

MEG is a GIS approach using aerial photography and river surveys to determine microhabitat availability for every cell in the river from Goodwin Dam to the mouth at 5 discharges (= Q's). In addition, we will be working in three dimensions. We intend to calculate physical habitat availability by volume. We intend to calculate fish habitat volume at each of 5 Q's. Furthermore, we intend to use preference. While preference curves are available in PHABSIM they are seldom used. We will also develop and use local curves for all species and life stages of interest. And, we will be including a microhabitat variable that PHABSIM does not address: velocity shear will be used to model the quality of cells.

Notes on the budget.

1. We agreed to breakdown costs with the MP region and Central California Area Office like this: 50% TSC Labor Costs will be paid through our S& T budget, 50% TSC Labor Costs will be paid through CCAO contributions (see Partners - Brian Deason), 100% of CCAO and MP region labor costs will be paid by the CCAO, and 100% of non-labor costs will be paid by CCAO. So in many tasks (e.g. acquire bathymetric data at 5 Q's) the cost to S & T is merely 50% of TSC labor costs to accomplish this task. So, if we choose LIDAR for bathymetric data - costs to our S & T budget would be only arranging the contractor to collect the data, process it, and deliver it to us.

2. In the budget we give examples of the discharges (Q's) at which we will work: 200, 300. 700, 1200, and 1500

cfs. We know that we will not be able to work at these exact discharges. The exact discharges will be dictated by water year and Central Valley operations. Discharge on the Stanislaus River only exceeds 1500 cfs during flood control operations. If hydrologic conditions present the opportunity, we may choose to forgo sampling at one of the lower discharges in order to quantify habitat above 1500 cfs.

XI. Team Qualifications

Team Qualifications
4000 characters including spaces)

Principal Investigator:

Bowen, Mark D., Ph.D. 1996. Utah State University. Dissertation entitled "Habitat Selection and Movement of a Stream-Resident Salmonid in a Regulated River and Tests of Four Bioenergetic Optimization Models." Recent Publications:

1) Bowen, M.D., S. Marques, L.G.M. Silva, V. Vono, and H.P. Godinho. 2006. Comparing on Site Human and Video Counts at Igarapava Fish Ladder, Southeastern Brazil. Neotropical Ichthyology 4: 291-294.

2) Bowen, M.D. and S.M. Nelson. 2003. Environmental Variables Associated with a Chinook Salmon Redd in Deer Creek, California. California Fish and Game 89(4):176-186.

3) Bowen, M.D., et al., 2003. Anadromous Salmonid Habitat in Three Watersheds of the Columbia Basin Project. USBR Denver Technical Service Center Rept. 140 pp.

4) Haefner, J.W., and M.D. Bowen. 2002. Physical-based Model of Fish Movement in Fish Extraction Facilities. Ecological Modelling 152: 227-245.

Brian Deason has been an Environmental Specialist at Reclamation's Mid Pacific Region in the Central California Area Office (CCAO) since 2004. Primary duties include: technical team lead for the New Melones Biological Science Group that is tasked to develop a biologically based instream flow schedule for the Stanislaus River, environmental review and compliance (e.g. NEPA, ESA) for various actions (e.g. water contracting, construction, operations), and COTR for the Stanislaus River Salmonid Habitat Use Investigation. He previously worked as an Aquatic Biologist for Reclamation's CCAO (2000-2004) and participated in various salmonid survey efforts in the Stanislaus and American Rivers. Recent publications:

1) Hannon, J. and B.Deason. 2005. American River steelhead (Oncorhynchus mykiss) spawning, 2001 - 2005. USBR. Sacramento. 48 pp.

2) Deason, B. and J.Hannon. 2005. Stanislaus River Salmonid Habitat Use Investigation Statement of Work and Request for Proposals.

3) Rinne, J.N. and B.Deason. 2000. Habitat availability and use by two threatened native fish species in southwestern rivers. Hydrology and Water Resources in the Southwest 30: 43-51.

John Hannon has been a fisheries biologist in Reclamation's mid-Pacific Region since 2001. He serves as salmonid biologist for Central Valley Project operations, conducts field research focusing on steelhead and Chinook in the American and Stanislaus Rivers and implements spawning gravel injection and evaluation projects. He was fisheries biologist on the Tongass National Forest, Southeast Alaska, 1990 - 2000: conducted monitoring and habitat restoration and protection projects for all five eastern Pacific Salmon species and steelhead. Recent publications:

1) Reclamation 2004. Long term Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment. USBR. Sacramento. 692p+app.

2) Hannon, J. 2002. Old Franks Fisheries Monitoring Recommendations and summary of 2002 Monitoring Activities. Tongass National Forest, Craig Ranger District. 15 pp. Link to series at http://home.surewest.net/hannon/OldFranks/oldfranksmapgeneric.html

Ron Sutton is a Fishery Biologist with over 20 years experience in the field and is certified as a Fisheries Scientist by the American Fisheries Society. He has extensive experience conducting instream flow studies throughout the United States using the Physical Habitat Simulation System (PHABSIM). Ron is currently working on several PHABSIM studies and other modeling efforts linking stream flow to salmonid and other fish habitat in the Pacific Northwest.

Katherine Potak Zehfuss received her Master's degree in Biomathematics and her Doctorate degree in Zoology from North Carolina State University. Her doctoral work focused on spatial and mathematical analyses of fish populations in several large rivers. In Colorado, she has worked as a Senior GIS Specialist for Science Applications International Corporation (SAIC). There she performed statistical analyses of GIS data.

Appendix B - Reaction Distance

Reaction distance (RD) was measured for Chinook salmon fry (n=26, length range 32-56 mm) and O.mykiss juveniles (n=3, length range 160-200 mm) in the Stanislaus River. The purpose of this survey was to confirm the 10 cm feeding velocity radius proposed for calculating shear. We measured RD as the farthest distance a fish moved from it focal position to capture a prey item (n=5 observations for each fish). For Chinook salmon fry, the average RD was 122 mm (2.9 body lengths) and the maximum RD was 266 mm (7 boy lengths). For O.mykiss juveniles, the average RD was 327 mm (1.8 body lengths) and the maximum RD was 425 mm (2.2 body lengths).

Reaction Distance Observations			
Bowen, Deason, and Kennedy			
2/15/07			
Species	Length	Maximum RD (mm)	Body Lengths
Chinook	45	200	4.4
Chinook	50	150	3.0
Chinook	45	100	2.2
Chinook	47	200	4.3
Chinook	36	80	2.2
Chinook	40	100	2.5
Chinook	56	150	2.7
Chinook	51	200	3.9
Chinook	39	78	2.0
Chinook	55	165	3.0
Chinook	45	112	2.5
Chinook	34	102	3.0
Chinook	35	105	3.0
Chinook	38	266	7.0
Chinook	34	136	4.0
Chinook	36	172	4.8
Chinook	38	60	1.6
Chinook	32	20	0.6
Chinook	40	120	3.0
Chinook	50	120	2.4
Chinook	39	78	2.0
Chinook	36	80	2.2
Chinook	42	120	2.9
Chinook	48	100	2.1
Chinook	46	90	2.0
Chinook	42	80	1.9
Chinook	Max RD	266	7.0
Chinook	Average RD	122	2.9
O.Mykiss	180	396	2.2
O.Mykiss	160	160	1.0
O.Mykiss	200	425	2.1
O.Mykiss	Max RD	425	2.2
O.Mykiss	Average RD	327	1.8

Appendix C –Velocity Array Lab Test

Laboratory Testing of Marsh McBirney Multi-Instrument Mount Stanislaus River Project

Project Contact: Brian Deason (916) 989-7173
Laboratory Testing Contact: Connie DeMoyer (303) 445-2152
Water Resources Research Laboratory (WRRL), Technical Service Center, Denver, CO
1/26/07-1/30/07

TEST 1 – Check calibration of 4 probes mounted on standard wading rod in Calibration Flume
Fixed point averaging with 30 s samples

Probe 6022 velocity (Ron - new instrument)
Readings 5.37, 5.45, 5.45, 5.36, 5.44 = 5.41 ft/s average

Probe 2271 velocity (WRRL - newly factory calibrated)
Readings 5.37, 5.36, 5.32, 5.40 = 5.36 ft/s average

Probe 5235 velocity (Ron - old instrument)
Readings 5.32, 5.30, 5.38, 5.31, 5.36 = 5.33 ft/s average

Probe 2740 velocity (Ron - old instrument)
Readings 5.40, 5.38, 5.41, 5.40, 5.36 = 5.39 ft/s average

Conclusion: Instruments are within 2% error of each other.

TEST 2 – Check Sontek 3-D FlowTracker (acoustic meter) on wading rod against Marsh-McBirney FloMate (electromagnetic meter) on wading rod in Calibration Flume

FlowTracker velocity (add air at pump for seeding)
Downstream component with 30 s samples
Readings 5.40 ± 0.04, 5.43 ± 0.03, 5.36 ± 0.03, 5.40 ± 0.12 = 5.40 ± 0.06 ft/s average

Marsh-McBirney FloMate 2740 velocity
Fixed point averaging with 30 s samples
Readings 5.22, 5.28, 5.33, 5.37, 5.39, 5.47 = 5.34 ft/s average

Conclusion: FloMate is calibrated relative to the FlowTracker.

TEST 3 – Check influence of ferrous frame by comparing velocity readings to wading rod readings in Calibration Flume

Probe 6022 mounted on ferrous mount
Fixed point averaging with 30 s samples
Readings 5.35, 5.38, 5.36, 5.36 = 5.36 ft/s average

Probe 6022 mounted on non-ferrous wading rod
Fixed point averaging with 30 s samples
Readings 5.37, 5.45, 5.45, 5.36, 5.44 = 5.41 ft/s average

Conclusion: Ferrous material does not affect readings.

TEST 4 – Quick check: Do readings interfere with each other at 5" spacing in Calibration Flume?
Two Marsh-McBirney probes were mounted adjacently on frame in Calibration Flume.
Fixed point averaging with 30 s samples

At 5” center-to-center probe spacing (Data from 1/26/07):
Probe 6022 velocity readings = 5.16, 5.28, 5.12 = 5.19 ft/s average
Probe 5235 velocity readings = 5.29, 4.83, 4.97 = 5.03 ft/s average

Note: Readings are likely lower on probe 5235 for 5” separation distance because the instrument was out of the constant velocity zone of the flow nozzle.

Conclusion: It appears that 5” spacing is sufficient for instruments to provide accurate readings. This will be tested more thoroughly in the 4 ft flume.

TEST 5 – Quick check: Do readings interfere with each other at 4" spacing in Calibration Flume?
Two Marsh-McBirney probes were mounted adjacently on frame in Calibration Flume.
Fixed point averaging with 30 s samples

At 4” center-to-center probe spacing (Data from 1/29/07):
Probe 6022 velocity readings = 2.88, 2.85, 2.88, 2.99, 2.81 = 2.88 ft/s average
Probe 5235 velocity readings = 2.92, 2.83, 2.71, 2.70, 3.02 = 2.84 ft/s average

Conclusion: It appears that 4” spacing is sufficient for instruments to provide accurate readings. This will be tested more thoroughly in the 4 ft flume.

TEST 6 – Check to see if 4 probes interfere with each other at 5" spacing in the 4 ft Flume

Four Marsh-McBirney probes were mounted on the frame in the 4 ft Flume.
Fixed point averaging with 30 s samples
Set-up: Probe 6022 in center; Probe 2740 at 12 o'clock; Probe 5235 at 3 o'clock; Probe 2271 at 9 o'clock

a. Velocity check with all 4 meters operating simultaneously with 5" spacing.

Probe 2740 velocity (12 o'clock) = 1.70, 1.73, 1.77, 1.73, 1.77, 1.76, 1.76, 1.76, 1.80, 1.74 = 1.75 ft/s average
Probe 6022 velocity (center) = 1.76, 1.68, 1.72, 1.64, 1.80, 1.76, 1.83, 1.76, 1.84, 1.78 = 1.76 ft/s average
Probe 5235 velocity (3 o'clock) = 1.50, 1.74, 1.65, 1.68, 1.61, 1.66, 1.63, 1.57, 1.60, 1.62 = 1.63 ft/s average
Probe 2271 velocity (9 o'clock) = 1.66, 1.61, 1.63, 1.77, 1.62, 1.83, 1.84, 1.78, 1.80, 1.82 = 1.74 ft/s average

b. Velocity check with one probe operating at a time with 5" spacing.

Probe 2740 velocity = 1.71, 1.70, 1.72, 1.71, 1.73 = 1.71 ft/s average
Probe 6022 velocity = 1.57, 1.59, 1.59, 1.55, 1.63 = 1.59 ft/s average
Probe 5235 velocity = 1.67, 1.60, 1.67, 1.59, 1.57 = 1.62 ft/s average
Probe 2271 velocity = 1.66, 1.62, 1.65, 1.65, 1.64 = 1.64 ft/s average

c. Compare measurements with 4 simultaneously operating Marsh-McBirney FloMates against a Sontek 3-D FlowTracker on wading rod at the same location in the 4 ft flume with 5" spacing.

Top tier:
Marsh-McBirney FloMate velocity readings = 1.62, 1.62 = 1.62 ft/s average
FlowTracker velocity readings = 1.56, 1.60 = 1.58 ft/s average

Bottom tier:
Marsh-McBirney FloMate velocity readings = 1.15, 1.14, 1.28, 1.25, 1.30, 1.28 = 1.23 ft/s average
FlowTracker velocity readings = 1.37, 1.33 = 1.35 ft/s average

Conclusion: 4 probes operating simultaneously will measure accurately at 5" spacing.

TEST 7 – Check to see if 4 probes interfere with each other at 4" spacing in the 4 ft Flume

a. Velocity check with all 4 meters operating simultaneously with 4" spacing.
Probe 2740 velocity (12 o'clock) = 1.54, 1.50, 1.52, 1.49, 1.50, 1.48, 1.52, 1.56, 1.42, 1.48, 1.49, 1.50, 1.46, 1.39 = 1.49 ft/s average
Probe 6022 velocity (center) = 1.47, 1.52, 1.61, 1.56, 1.68, 1.37, 1.42, 1.08, 1.09, 0.96, 1.38, 1.43, 1.31, 1.11 = 1.36 ft/s average
Probe 5235 velocity (3 o'clock) = 1.20, 1.24, 1.23, 1.22, 1.17, 1.29, 1.29, 1.53, 1.44, 1.41, 1.48, 1.12, 1.08, 1.28 = 1.28 ft/s average
Probe 2271 velocity (9 o'clock) = 1.28, 1.20, 1.21, 1.14, 1.29, 1.28, 1.29, 1.51, 1.52, 1.40, 1.38, 1.44, 1.51, 1.34 = 1.34 ft/s average

b. Velocity check with one probe operating at a time with 4" spacing.
Probe 2740 velocity (12 o'clock) = 1.51, 1.50, 1.48, 1.50 = 1.50 ft/s average
Probe 6022 velocity (center) = 1.20, 1.28, 1.17, 1.26, 1.29, 1.29 = 1.25 ft/s average
Probe 5235 velocity (3 o'clock) = 1.23, 1.18, 1.26, 1.23 = 1.23 ft/s average
Probe 2271 velocity (9 o'clock) = 1.34, 1.27, 1.35, 1.33 = 1.32 ft/s average

c. Compare measurements with 4 simultaneously operating Marsh-McBirney FloMates against a Sontek 3-D FlowTracker on wading rod at the same location in the 4 ft flume with 4"spacing.

Top tier:
Marsh-McBirney FloMate velocity readings = 1.67, 1.69 = 1.68 ft/s average
FlowTracker velocity readings = 1.63, 1.65 = 1.64 ft/s average

Bottom tier:
Marsh-McBirney FloMate velocity readings = 1.36, 1.33 = 1.35 ft/s average
FlowTracker velocity readings = 1.43, 1.44 = 1.44 ft/s average

Conclusion: 4 probes operating simultaneously will measure accurately at a 4" spacing.

TEST 8 – Check to see if sounding weight interferes with velocity measurements in the 4 ft Flume
The sounding weight was extended 1 ft below the frame with a rigid extension piece to allow the weight to control the direction of flow while minimizing its influence on measurements.

Sounding weight attached to frame
Probe 2740 velocity (12 o'clock) = 1.97, 2.02, 2.04, 2.02, 2.02 = 2.01 ft/s average

Probe 6022 velocity (center) = 1.92, 2.12, 1.70, 1.69, 1.85 = 1.86 ft/s average
Probe 5235 velocity (3 o'clock) = 1.82, 1.82, 2.05, 1.87, 1.93 = 1.90 ft/s average
Probe 2271 velocity (9 o'clock) = 1.75, 1.86, 1.81, 1.71, 1.93 = 1.81 ft/s average

Sounding weight lowered 1 foot below the frame

Probe 2740 velocity (12 o'clock) = 1.71, 1.65, 1.57, 1.52, 1.59 = 1.61 ft/s average
Probe 6022 velocity (center) = 1.87, 2.02, 1.53, 1.33, 1.74 = 1.70 ft/s average
Probe 5235 velocity (3 o'clock) = 1.66, 1.48, 1.60, 1.79, 1.81 = 1.67 ft/s average
Probe 2271 velocity (9 o'clock) = 1.71, 1.83, 1.71, 1.79, 1.58 = 1.72 ft/s average

Conclusion: The sounding weight may cause flow acceleration in the vicinity of the weight, causing readings to be slightly higher when the weight is attached directly to the frame. The pattern was not observed during the FlowTracker tests.

Recommendations for Field Study

1.) Bring wire ties to hold instrument cables together (recommended every few feet of cable) and plenty of D batteries.
2.) Two people are needed to lower the sounding weight and cables so that the cables do not get intertwined with the frame or the instruments.
3.) Attach the fin at the top of the frame on the downstream side with the provided attachment piece. The fin counteracts drag from the frame to maintain the proper orientation of the sounding weight.
4.) The sounding weight may cause slight flow acceleration in the vicinity of the weight. For the nature of these field measurements, it is recommended to attach the sounding weight directly to the frame so that data can be collected closer to the bed.
5.) Instruments can be located 4" apart without experiencing interference. If you encounter "noise" or "lost connection" errors, clear & restart the measurement and/or look at the bulbs to see if they are covered (with debris or intertwined cables) or damaged. If you are still not receiving measurements, extend the separation distance to 5".
6.) Shear zones were not analyzed in depth in the laboratory. If the frame is placed in a strong shear zone, observe frame position to make sure that it is oriented correctly.
7.) Use the torpedo-shaped sounding weight instead of the flat sounding weight. The flat weight does not hold proper orientation into the flow with or without the frame attached.

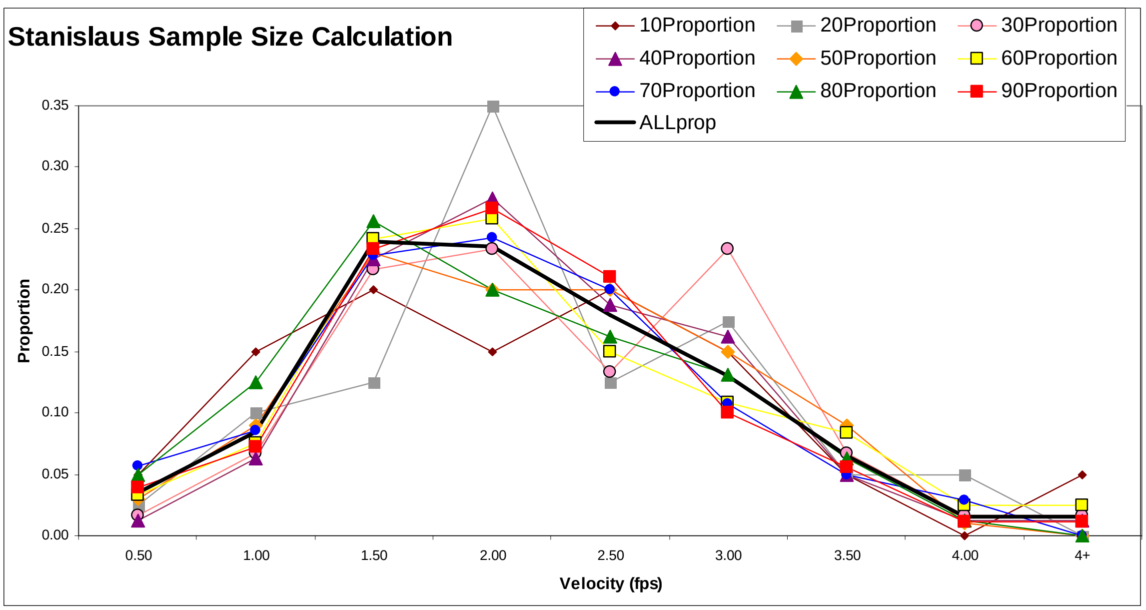
Photographs - Laboratory Testing of Marsh McBirney Multi-Instrument Mount Stanislaus River Project

Velocity array set up with downrigger and directional fin.

Testing the velocity array in experimental flume at Denver Technical Service Center.

Appendix D – Minimum Sample Size

For Microhabitat Availability, we determined that a total of 40 points need to be surveyed to describe the habitat availability within each of the six mesohabitat types. We conducted a convergence analysis to determine the minimum number of sample positions needed to adequately describe the distribution of microhabitat parameters in each mesohabitat type. SHUPI personnel collected 200 velocity measurements in a riffle at Knight's Ferry. We plotted the distribution of these 200 measurements as well as random draws of 10, 20, 30,…., 200 points. The figure below shows that when we drew 20 there is a big difference in the distribution compared to when we drew 200. However, at a draw of 40, there is no statistical difference in n=40 and n=200 using a Chi square goodness of fit test (Sokal and Rohlf, 1981).



Appendix E – GPS Data Dictionaries

Microhabitat Use (MU) Definitions

Name	Definition	Data Type	Format	Units
MarkNum	Unique marker number	Numeric	000	N/A
Species	Select from a dropdown menu: • Chinook • O.mykiss • Other	Text	N/A	N/A
TLength	Total body length measured from the tip of the nose to the longest tip of the caudal fin	Numeric	000	mm
D2Subst	Vertical distance from the substrate to the nose of the fish	Numeric	000	cm
ColDepth	Total water column depth measured at the fish position	Numeric	000	cm
FocalVel	Velocity measured in the water column at the nose of the fish (focal position)	Numeric	0.00	ft/sec
3FedVel	Velocity measured at 3 o'clock position (oriented toward flow) relative to the focal velocity.	Numeric	0.00	ft/sec
9FedVel	Velocity measured at 9 o'clock position (oriented toward flow) relative to the focal velocity	Numeric	0.00	ft/sec
12FedVel	Velocity measured at 12 o'clock position (oriented toward flow) relative to the focal velocity	Numeric	0.00	ft/sec
DTEdge	Distance to closest submerged cover that the observed fish could utilize to escape a piscine predator	Numeric	000.00	m
Edge_Type	Selectable list with different cover code types (to be determined)	Dropdown menu	N/A	N/A
Substrate	Selectable list with dominant and sub-dominant substrate types (to be determined)	Dropdown menu	N/A	N/A
Comment1	Optional space to enter explanatory data	Text	N/A	N/A
Comment2	Optional space to enter explanatory data	Text	N/A	N/A
Date/Time	Auto-fill field	Date/Time	N/A	N/A

Microhabitat Availability (MA) Definitions

Name	Definition	Data Type	Format	Units
MesoHab	Select from a dropdown menu: • LoVelNoCov • LoVelCov • MedVelNoCov • MedVelCov • HiVelNoCov • HiVelCov	Text	N/A	N/A
Point_#	Sequential auto-fill field for tracking point position number (1-40)	Numeric	00	N/A
ColDepth	Total water column depth measured at the point position	Numeric	000	cm
FocVelBot	Focal velocity measured at the bottom of water column.	Numeric	0.00	ft/sec
3VelBot	Velocity measured at 3 o'clock position (oriented toward flow) relative to the focal velocity.	Numeric	0.00	ft/sec
9VelBot	Velocity measured at 9 o'clock position (oriented toward flow) relative to the focal velocity.	Numeric	0.00	ft/sec
12VelBot	Velocity measured at 12 o'clock position (oriented toward flow) relative to the focal velocity.	Numeric	0.00	ft/sec
Substrate	Selectable list with dominant and sub-dominant substrate types (to be determined)	Dropdown menu	N/A	N/A
DC0	Distance to closest submerged cover that a 0+ steelhead or Chinook salmon could utilize to escape a piscine predator	Numeric	000.00	m
DC1	Distance to closest submerged cover that a 1+ steelhead could utilize to escape a piscine predator	Numeric	000.00	m
DTEdge	Distance to closest submerged cover that the observed fish could utilize to escape a piscine predator	Numeric	000.00	m
Edge_Type	Selectable list with different cover code types (to be determined)	Dropdown menu	N/A	N/A
FocVelCol	Focal velocity measured at 0.6 the water column depth.	Numeric	0.00	ft/sec
3VelCol	Velocity measured at 3 o'clock position (oriented toward flow) relative to the focal velocity.	Numeric	0.00	ft/sec
9VelCol	Velocity measured at 9 o'clock position (oriented toward flow) relative to the focal velocity	Numeric	0.00	ft/sec
12VelCol	Velocity measured at 12 o'clock position (oriented toward flow) relative to the focal velocity	Numeric	0.00	ft/sec
Comment1	Optional - space to enter explanatory data	Text	N/A	N/A
Comment2	Optional - space to enter explanatory data	Text	N/A	N/A
Date/Time	Auto-fill field	Date/Time	N/A	N/A

Mesohabitat Mapping Definitions

Name	Definition	Data Type	Format	Units
MesoHab	Select from a dropdown menu: • LoVelEdge • LoVelNoEdge • MedVelEdge • MedVelNoEdge • HiVelEdge • HiVelNoEdge	Text	N/A	N/A
TopWidth	Mesohabitat width at top (upstream) transect	Numeric	000.00	m
TopDepth	Water column depth measured 1 meter downstream of the TopWidth transect in the middle of the mesohabitat.	Numeric	000.00	cm
MidWidth	Mesohabitat width at longitudinal midpoint of the mesohabitat polygon	Numeric	000.00	m
MidDepth	Water column depth measured at the MidWidth transect in the middle of the mesohabitat.	Numeric	000.00	cm
BotWidth	Mesohabitat width at the bottom (downstream) extent of the mesohabitat	Numeric	000.00	m
BotDepth	Water column depth measured 1 meter upstream of the BotWidth transect in the middle of the mesohabitat	Numeric	000.00	cm
Vel_Top	Water velocity measured at the top (upstream) of the mesohabitat	Numeric	0.00	ft/sec
Vel_Mid	Water velocity measured at the midpoint of the mesohabitat	Numeric	0.00	ft/sec
Vel_Bot	Water velocity measured at the bottom (downstream) of the mesohabitat	Numeric	0.00	ft/sec
Edge_Type	Selectable list with different cover code types (to be determined)	Dropdown menu	N/A	N/A
%_Cover	Estimate of the observed cover relative to the total size of the mesohabitat will be recorded (0-100%, in 5% increments).	Numeric	000	%
Comment1	Optional - space to enter explanatory text data	Text	N/A	N/A
Comment2	Optional - space to enter explanatory text data	Text	N/A	N/A
Date/Time	Auto-fill field	Date/Time	N/A	N/A

Mesohabitat Ground-Truth

Name	Definition	Data Type	Format	Units
MesoHab	Select from a dropdown menu: • LoVelNoCov • LoVelCov • MedVelNoCov • MedVelCov • HiVelNoCov • HiVelCov	Text	N/A	N/A
TopWidth	Mesohabitat width at top (upstream) transect	Numeric	000.00	m
TopDepth	Water column depth measured 1 meter downstream of the TopWidth transect in the middle of the mesohabitat.	Numeric	000.00	cm
MidWidth	Mesohabitat width at longitudinal midpoint of the mesohabitat polygon	Numeric	000.00	m
MidDepth	Water column depth measured at the MidWidth transect in the middle of the mesohabitat.	Numeric	000.00	cm
BotWidth	Mesohabitat width at the bottom (downstream) extent of the mesohabitat	Numeric	000.00	m
BotDepth	Water column depth measured 1 meter upstream of the BotWidth transect in the middle of the mesohabitat.	Numeric	000.00	cm
Vel_Top	Optional – velocity measured in the mesohabitat at top transect.	Numeric	0.00	ft/sec
Vel_Mid	Optional – velocity measured in the mesohabitat at the middle transect	Numeric	0.00	ft/sec
Vel_Bot	Optional – velocity measured in the mesohabitat at the bottom transect	Numeric	0.00	ft/sec
Edge_Type	Selectable list with different cover code types (to be determined)	Dropdown menu	N/A	N/A
%_Cover	Estimate of the observed cover relative to the total size of the mesohabitat will be recorded (0-100%, in 5% increments).	Numeric	000	%
Comment1	Optional - space to enter explanatory text data	Text	N/A	N/A
Comment2	Optional - space to enter explanatory text data	Text	N/A	N/A
Date/Time	Auto-fill field	Date/Time	N/A	N/A